THE PRINCIPLES OF MR. HARRISON'S TIME-KEEPER, WITH PLATES OF THE SAME.

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PREFACE.

THE original drawings, from which theſe plates were engraved, together with the written paper annexed, intituled, PRINCIPLES OF MR. HARRISON'S TIME-KEEPER, were delivered to the Commiſſioners appointed by act of parliament for the diſcovery of the longitude at ſea, by Mr. John Harriſon and Mr. William Harriſon his ſon, upon oath, as containing a full explanation of the principles upon which Mr. John Harriſon's watch or time-keeper for finding the longitude at ſea is conſtructed.

Mr. Harriſon and his ſon gave alſo, upon oath, to the Reverend John Mitchell, the Reverend William Ludlam, and Mr. John Bird, gentlemen well-ſkilled in mechanics, and Mr. Thomas Mudge, Mr. Larcum Kendal,

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Kendal, and Mr. William Matthews, watch-makers, by appointment of the board of longitude, and myſelf, ſuch further explanation of the conſtruction of the ſaid watch, by word of mouth and experimental exhibitions, as we required; producing the watch, taking it to pieces in our preſence, and anſwering to ſuch queſtions as we propoſed relative thereto. Some notes taken by myſelf on this occaſion I have ſubjoined hereto.

The original drawings of the watch were delivered to me at the board of longitude, which I have ſince cauſed to be carefully engraved, under my own eyes, at the Royal Obſervatory, and think I can anſwer, that the lines on the copper-plates every-where correſpond with the meaſure of the drawings within one, or at moſt two breadths of the lines, which are ſo very fine. Nevertheleſs, the reader muſt not expect to find the impreſſions taken off upon common paper agree ſo nearly, either with the originals or with themſelves, owing

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owing to the ſhrinking of the paper after the water has been preſſed out of it in going through the preſs. But, for the ſake of the curious, and particularly artiſts who may be deſirous to conſtruct other watches after the model of Mr. Harriſon's, I have cauſed a few impreſſions of the plates to be taken off upon India paper; which, if it be only made a little damp, by being put for a few minutes between two wet ſheets of paper, will receive the impreſſion from the plates perfect, and will not ſhrink at all in the drying.

It may not be improper to take notice here of a difference in the poſition of the pallets in the 8th and 9th figures, plates VI. and VII. which might otherwiſe puzzle the inſpector, or, at leaſt, induce him to think there was ſome error made in engraving the plates from the original.

In figure 8th, the centre of the curve of the pallets lies in the circumference of the dotted circle, whoſe radius is two fifths of the radius of the circle deſcribed by

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by the edge of the pallets; but, in figure 9th, the centre of the pallets lies juſt without the circumference of the little black circle, repreſenting the ſpindle, whoſe radius is one fourth of the radius of the circle deſcribed by the edge of the pallets. The latter figure ſhews Mr. Harriſon's former deſign, which he has ſince altered, as is repreſented in the 8th figure.

NOTES

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NOTES

TAKEN AT THE

DISCOVERY

OF

MR. HARRISON'S TIME-KEEPER.

THE balance naturally vibrates largeſt arcs, when in a horizontal poſition; next greateſt, when the hours XII and VI are uppermoſt, and the watch is in a vertical poſition; leaſt, when the hours III and IX are uppermoſt.

Large arcs are naturally performed in leſs time than ſmall ones. This Mr. Harriſon inferred, becauſe the

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watch, before any correction was applied, went ſlower in a vertical poſition than in the horizontal one, and the vibrations are viſibly larger in the latter caſe.

The watch is adjuſted to vibrate great and ſmall arcs in equal times, in the following manner:

To go the ſame when placed vertically with the hours III, VI, IX, XII upwards ſucceſſively, by making the weight of the balance different in different parts.---To go the ſame when placed horizontal as when vertical, by the joint effect of the back of the pallets and the cycloid-pin.

The curve of the back of the pallets is an arch of a circle, whoſe centre lies in the line joining the edges of the pallets and the centre of the ſpindle, the diſtance of the two centres being two fifths, and the radius of the curve of the pallets three fifths of the radius of the circle deſcribed by the edge of the pallets.

The action of the cycloid-pin, when it touches the balance-ſpring, tends to quicken its vibrations; and the ſpring, leaving the pin for a longer time in the large vibrations than in the ſmall ones, is leſs accelerated by it in the former than in the latter caſe; and, conſequently, the action of the pin tends to reduce the time of the different

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different vibrations nearer to equality. The cycloid-pin was not applied to the watch till after it came back from the voyage to Jamaica.

If the balance-ſpring is too ſtrong, it muſt be made weaker by rubbing it away a little; but, if it be too weak, it muſt be changed for a ſtronger.

The balance-ſpring is faſtened at the outer end to a ſtud, which takes off the plate with a ſcrew, and is put on again with the ſame ſcrew, and ſteady-pins, exactly in the ſame poſition as before, without undoing the faſtening of the ſpring to the ſtud at the end.

There is no adjuſtment for mean time, as in common watches; there was once, but it did not anſwer.

As ſoon as the watch is put together, Mr. Harriſon ſays, it will ſhew its rate of going in three hours accurately the ſame which it will keep afterwards; ſo that he can ſoon determine it by compariſon with his pendulum clock.

The balance-ſpring, when at reſt, touches the cycloid-pin; and does not begin to leave it, till the balance has vibrated an arch of forty-five degrees beyond the point of reſt, while the ſpring is in the ſtate of coiling itſelf up.

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The thermometer kirb is compoſed of two thin plates of braſs and ſteel rivetted together in ſeveral places, which, by the greater expanſion of braſs than ſteel by heat, and contraction by cold, becomes convex on the braſs ſide in hot weather, and convex on the ſteel ſide in cold weather; whence, one end being fixed, the other end obtains a motion correſponding with the changes of heat and cold, and the two pins at this end, between which the balance-ſpring paſſes, and which it touches alternately as the ſpring bends and unbends itſelf, will ſhorten or lengthen the ſpring, as the changes of heat and cold would otherwiſe require to be done by the hand, in the manner uſed for regulating a common watch.

Mr. Harriſon requires cold weather for adjuſting the thermometer kirb, and he places the watch near a fire, with a common thermometer by it, to try if it keeps the ſame time as in the cold air. If not, he alters or adjuſts the thermometer kirb till it goes the ſame in theſe two different degrees of temperature of the air.

The thermometer kirb takes heat ſooner than the balance-ſpring, and he thence concludes that braſs takes heat ſooner than ſteel, and that the braſs rods of a grid-

iron.

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iron pendulum ſhould be made thicker than the ſteel ones.

Whilſt the heat is increaſing, the watch will ſometimes go one tenth of a ſecond ſlower in three hours, than when the heat is come to a ſtand.

The effect of the thermometer is increaſed by rubbing the ſides thinner, and is leſſened by thickening the edge by burniſhing it.

Mr. Harriſon adjuſts the thermometer kirb firſt, that is to ſay, before he adjuſts the watch to go the ſame in different poſitions.

The watch may be put with figure XII turned each day alternately different ways, for fear one part of the box in which it is kept may be hotter than the other.

The force or momentum of the balance, Mr. Harriſon ſays, is as the ſquare of its diameter, alſo as the ſquare of the velocity, its weight being given.

The momentum of the balance acquired by increaſing the velocity is better than that acquired by increaſing the weight; as friction is not thereby increaſed, perhaps, if any thing, diminiſhed, and the reſiſtance of the air only is increaſed, the effect of which is tolerably uniform, and of great ſervice.

The

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The diameter of the balance is 2,2 inches, of the plate 3,8 inches.

The balance ſhould be a little larger, or $2\frac{1}{4}$ inches, according to a memorandum taken by Mr. Bird.

The watch makes juſt five beats in a ſecond of time.

If the balance vibrated faſter, the reſiſtance of the air would be too great.

A pocket watch of this kind would do better with ſix beats in a ſecond.

A certain ſize is beſt for the pallets, or rather a certain proportion between the diameter of the circle deſcribed by the edge of the pallets and the diameter of the balance-wheel. This was firſt ſuggeſted to Mr. Harriſon from bell-ringing; for he could bring the bell better into a motion, by touching it from time to time ſomewhere near the centre than near the circumference; becauſe in the firſt caſe his hand moved quick enough to follow the bell.

The grand principle of the watch is that of giving the greateſt motion poſſible to the balance with a given force. This is done by the ſcaping and proper quantity of the arc deſcribed.

This

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This note was communicated by Mr. Mudge, as alſo the following; That the balance, by the force from the wheels, without its ſpring, tends to vibrate once in two ſeconds.

There are four ſprings in the watch; firſt, a main ſpring; ſecondly, a ſpring in the inſide of the fuſee, to keep it going while it is winding up; thirdly, a ſpring, which is wound up eight times every minute; fourthly, the balance-ſpring. The three firſt were made by Maberley.

The fuſee has ſix turns and a quarter.

The fly ſerves to moderate the velocity with which the ſpring neareſt the balance would otherwiſe be wound up.

The pivot-holes are all made in rubies, with diamonds at the ends.

The pallets are diamonds.

One end of the watch in the late voyage to Barbadoes was ſet higher, becauſe it was not equally adjuſted in all poſitions. Alſo it was altered and brought back to the ſame poſition, with reſpect to the horizon, as the ſhip lay down on the one or the other

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tack, by the help of a moveable box, with a divided arch.

Mr. William Harriſon reckons the greateſt roll of a ſhip fifteen degrees, and the greateſt lie-down, when going upon one tack, twelve degrees.

Hold the watch a little back, when in a vertical poſition, that the face may be a little up.

If the balance-ſpring be not exactly parallel to the plates, there will be a ſmall difference in the going of the watch, when the face is up or down.

Care is to be uſed in moving the watch, or in turning it about, in order to wind it up, not to give it any quick circular motion in the plane of the balance, as it might poſſibly ſtop it. A pocket-watch, which Mr. Harriſon has made of this kind, once ſtopped this way. Turn the watch over upon ſome diameter of the dial-plate, as an axis, in order to bring it into a convenient poſition, when you want to wind it up.

Oil muſt be applied to the pallets and pivot-holes of the watch, but very ſparingly.

The watch will go three years without requiring to be cleaned.

At

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At the time of the diſcovery, in Auguſt 1765, Mr. Harriſon ſaid, that the watch then went a little ſlower than it had done, owing to its wanting to be cleaned, viz. two or three ſeconds per day.

The watch ſhould have a cap, and no outer caſe, the wooden box, in which it ſhould be kept, ſerving that purpoſe better.

NEVIL MASKELYNE,
Astronomer Royal.

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PRINCIPLES

OF

MR. HARRISON'S TIME-KEEPER.

IN this Time-keeper there is the greateſt Care taken to avoid Friction as much as can be, by the Wheels moving on ſmall Pivots, and in Ruby-holes, and high Numbers in the Wheels and Pinions.

The Part which meaſures Time goes but the eighth Part of a Minute without winding up; ſo that Part is very ſimple, as this Winding-up is performed at the Wheel next to the Balance-wheel; by which Means, there is always an equal Force acting at that Wheel, and all the reſt of the Work has no more to do in meaſuring Time, than the Perſon that winds them up once a Day.

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There is a Spring in the Inſide of the Fuſee, which I will call a ſecondary Main-ſpring. This Spring is always kept ſtretched to a certain Tenſion by the Main-ſpring, and during the Time of winding up the Time-keeper, at which Time the Main-ſpring is not ſuffered to act, this ſecondary Spring ſupplies its Place.

In common Watches in general the Wheels have about One-third the Dominion over the Balance that the Balance-ſpring has; that is, if the Power the Balance-ſpring has over the Balance be called *Three*, that from the Wheels is *One*; but in this my Time-keeper, the Wheels have only about *One-eightieth* Part of the Power over the Balance that the Balance-ſpring has; and it muſt be allowed, the leſs the Wheels have to do with the Balance, the better. The Wheels in a common Watch having this great Dominion over the Balance, they can, when the Watch is wound up, and the Balance at reſt, ſet the Watch a-going; but when my Time-keeper's Balance is at reſt, and the Spring is wound up, the Force of the Wheels can no more ſet it a-going, than the Force of the Wheels of a common Regulator can, when the Weight is wound up, ſet the Pendulum a-vibrating; nor will the Force from the Wheels move the Balance, when at reſt, to a greater Angle

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Angle in Proportion to the Vibration that it is to fetch, than the Force of the Wheels of a common Regulator can move the Pendulum from the Perpendicular, when it is at reſt.

My Time-keeper's Balance is more than three times the Weight of a large fized common Watch-balance, and three times its Diameter; and a common Watch-balance goes through about ſix Inches of Space in a Second, but mine goes through about twenty-four Inches in that Time: So that had my Time-keeper only theſe Advantages over a common Watch, a good Performance might be expected from it. But my Time-keeper is not affected by the different Degrees of Heat and Cold, nor Agitation of the Ship; and the Force from the Wheels is applied to the Balance in ſuch a Manner, together with the Shape of the Balance-ſpring, and (if I may be allowed the Term) an artificial Cycloid, which acts at this Spring; ſo that from theſe Contrivances, let the Balance vibrate more or leſs, all its Vibrations are performed in the ſame Time; and therefore, if it go at all, it muſt go *true*. So that it is plain from this, that ſuch a Time-keeper goes intirely from Principle, and not from Chance.

The

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The following is a Deſcription of the DRAWINGS from which my *fourth* Time-keeper was made, and the Drawings are alſo hereunto annexed.

FIG. 1.

AA is the Chain-barrel, and BB is a Section of it.
CC is the Spring-barrel, and DD is a Section of it.
EE is a Ratchet at the Spring-barrel, and FF is a Section of it. This Ratchet is ſcrewed to the Spring-barrel by four ſmall Screws at *aaaa*. There is a Hole in the Pillar-plate of the Diameter from the dotted Lines *bb*, and that Part of the Spring-barrel *cc* is to move in this Hole without any Shake, in order to ſet the Spring up. The Ratchet is alſo ſhewn in Figure 13th, by the Circle *bb*, and it has thirty Teeth, and *c* is the Click that holds it.

FIG. 2.

AA is the Braſs Edge, BB the Hole in the Middle of it, and CC is a Section of it. This Braſs Edge is ſupported by ſix Pillars, and their Places are repreſented in Figures 13 and 14, by ſix Circles *aaaaaa*.

FIG.

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FIG. 3.

A A is the first Wheel, and *aaaa* is a Section of it. *bbb* is a Section of the Fusee. B B is the outer Diameter of a Ratchet which is fixed to the Inside of the Fusee, and the inner Circle C C is its inner Diameter, and it has 55 Teeth in it. *dddd* is what I call the perpetual Ratchet, of which *cccc* is a Section; there is a Ratchet with 75 Teeth in it on that Part marked *ff*, this is also shewn in Figure 13 by the Circle *ee*, and this perpetual Ratchet is to carry the Barrel D D, which Barrel contains the secondary Main-spring, and will be in the Inside of the Fusee at *gg*, and at that Part of the first Wheel *hh* the inner End of this Spring is to act, as that Part *hh* will be its Arbor. The dotted Lines E represent the Grooves in the Fusee. The dotted Lines *ll* represent the upper Plate. The dotted Lines *mm* represent the Pillar Plate. The dotted Lines *nn* represent the Cock, which carries the lower End of the Arbor of the first Wheel. This Cock is also represented in Figure 13 at *dddd*. The Ratchet *ee* in Figure 13 has two Clicks, whose Centres are at *ff*, and

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and *g g* are the Springs which act at these Clicks. In Figure 14 *b b* represents the first Wheel with 96 Teeth, acting in a Pinion of 21 at *c*.

FIG. 4.

A A represents the second Wheel acting in a Pinion at *a*. B B represents the third Wheel, which is concave, and acts in a Pinion at *b*. The second Wheel is described in Figure 14 by the Circle *d d*, and acts in a Pinion of 18 at *e*. The third Wheel is represented in Figure 14 by the Circle *f f*, acting in a Pinion of 16 at *g*.

Note, The third Wheel is larger than is represented in Figure 14, and has 144 Teeth, and the second Wheel has 120 Teeth.

FIG. 5.

A A represents the contrate Wheel, B B a Section of it, with a Section of the Spring-barrel *a a*. At *c c* is a Piece with eight Pins in it, that discharges the running Wheels every eighth Part of a Minute. This Wheel is also represented in Figure 14 by the Circle *h h*; it has 120 Teeth, and acts in a Pinion of 12 at *i*.

FIG.

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FIG. 6.

Is the Dittent, by which is the Diſcharge for winding up eight Times in a Minute. The Part *a* acts at the eight Pins on the contrate Wheel-arbor. *b* is a Roller acting againſt a Piece of Braſs on the fifth Wheel-arbor. *c* is a Piece that ſtops againſt a Pin in the Rim of the fifth Wheel. *dd* are Pieces of Braſs to make it in an Equilibrium in itſelf; and E is the Spring which acts upon it. The Centre of this Dittent is at *x* in Figure 14.

FIG. 7.

A is a Section of the Frame, with the Balance-cock, the Slide, and the Braſs Edge; and *a* is the Centre of the Joint-pin. B is a Section, where *aa* repreſents the Balance-cock, *bb* the third Wheel-cock.

c the Cock at the End of the contrate Wheel.

d the Cock at the End of the fourth Wheel.

e the fourth Wheel.

f the Follower.

g the Balance-wheel.

b the Potence.

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i the Balance-wheel Pinion.

k the Counter-potence, which alſo carries the other End of the fourth Wheel.

m the Spring-barrel.

n the Hook in it, where the out End of the Spring hangs.

o the Hook at the contrate Wheel, where the inner End of the Spring is hung.

r the fifth Wheel, with the Pin where the Dittent is to ſtop.

s the upper Plate.

T the Pillar-plate.

FIG. 8.

a a are the Pallets of ten times the Size that they are in the Time-keeper. The dotted Lines from 24ths. of the Circle, ſhew the Power the Balance-wheel has to impede the Motion of the Balance by the Declivity on the Back of the Pallets, at any the ſame time whenever it ſhall have the greateſt Power to give it Motion.

FIG.

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FIG. 9.

Is to ſhew the Proportion between the Balance, the Balance-wheel, the Balance-wheel Teeth, the Pallets, and at what Diſtance the Wheel acts from the Centre of the Balance. AA repreſents the Balance, BB the Balance wheel, *aa* the Pallets, and *bbbbbb* the Balance-wheel Teeth.

FIG. 10.

A is the Counter-potence, with the Follower *a*, and a ſmall Screw at *c*, to ſtop when at its proper Place, and *x* is the Centre of the fourth Wheel.

B is the Cock for the Minute-wheel.

C is the Steel Bridge.

D is a Cock for the contrate Wheel.

E is a Cock at the firſt Wheel.

F is a Cock at the contrate Wheel on the Pillar-plate.

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FIG. 11.

Is the Dittent, which is to ſtop the Balance before the Watch be down. It turns upon a Centre at *t* in Figure 14. A is the Locking-ſpring.

FIG. 12.

AA repreſents the upper Plate. BB the Balance.
aa the Thermometer.
bb the Balance-ſpring.
cc Slider to adjuſt the Thermometer end-way.
d the Stud.
e the artificial Cycloid.
f a Piece to adjuſt it ſo as to bear properly againſt the Spring.

FIG. 13.

aaaaaa the Feet of the Braſs Edge.
bb the Ratchet at the Spring-barrel.
c the Click.
dddd the Cock at the End of the firſt Wheel.

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ee a Ratchet.
ff the Centres of the two Clicks which act in it.
gg the two Springs that act at them.
hhhhhh the six Pillars of the Frame.
ii the Steel Bridge.
kkk two Wheels that carry the Seconds, one being on the contrate Wheel-arbor, the other moving on the Cannon-pinion.
l the Cannon-pinion.
mm the Minute-wheel.
n the Hour-pinion.
oo the Hour-wheel.

FIG. 14.

aaaaaa the six Pillars of the Brass Edge.
bb the first Wheel.
c the Centre-pinion.
dd the second Wheel.
e the second Pinion.
ff the third Wheel.
g the third Pinion.
hh the contrate Wheel, and the fourth Wheel.

i the

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i the Balance-wheel Pinion.
k the fourth Pinion.
ll the fifth Wheel.
m the fifth Pinion.
nn the Fly.
oo the Balance-wheel.
p the Potence.
rrrrrr the ſix Pillars of the Frame.
s the Stud.
t the Centre of the Dittent, to ſtop the Balance.
x the Centre of the diſcharging Dittent.
uu the upper Plate.
zz the Pillar-plate.

FIG. 15.

Is what was deſigned for the Work on the upper Plate, which is now done in the Manner as repreſented in Figure 12.

For

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For tempering the Balance-ſpindle, the Balance-ſpring, and the Pinions.

Before their being immerſed in the Metal (as juſt melted) let them be oiled over.

The Heat for the Balance-ſpindle 567 on Fahrenheit's Scale, the which is given by one of Pewter to 12 of Lead; but for the Balance-ſpring and the Pinions, let the Mixture be One of Pewter to 17 of Lead.

Each Turn of the firſt Wheel (or Fuſee) is $4\frac{4}{7}$ Hours; ſo $5\frac{1}{4}$ of its Turns is juſt 24 Hours; and $6\frac{1}{4}$ is $28\frac{4}{7}$ Hours; and $6\frac{9}{16}$ Turns equal to 30 Hours.

FINIS.

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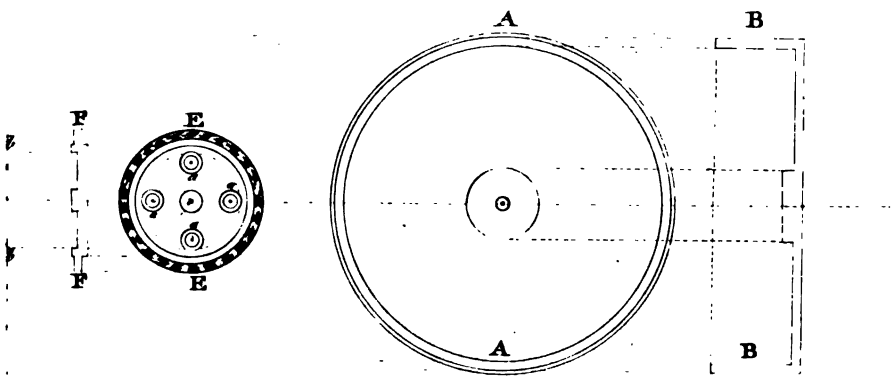
Fig. 1.



...r.....about 1,64 of 1/4 Inch

...ntre of the Chain Barrel about 0,38.....

.....0,23.....

.....0,215.....

...within.....1,4 Inch?

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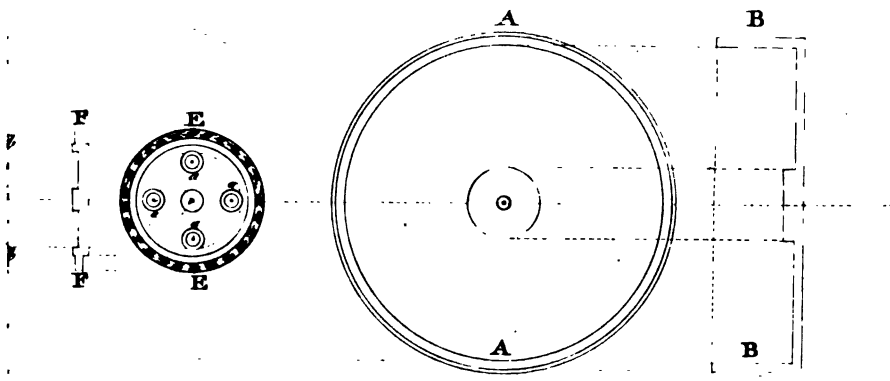
Fig: 1.



r.....about 1,64 of 1/4 Inch

ntre of the Chain Barrel about 0,38.....

.....0,23.....

.....0,215.....

within.....1,4 Inch.

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Fig. 2.

Height of these pillars about 0,55 of 1/4 Inch.

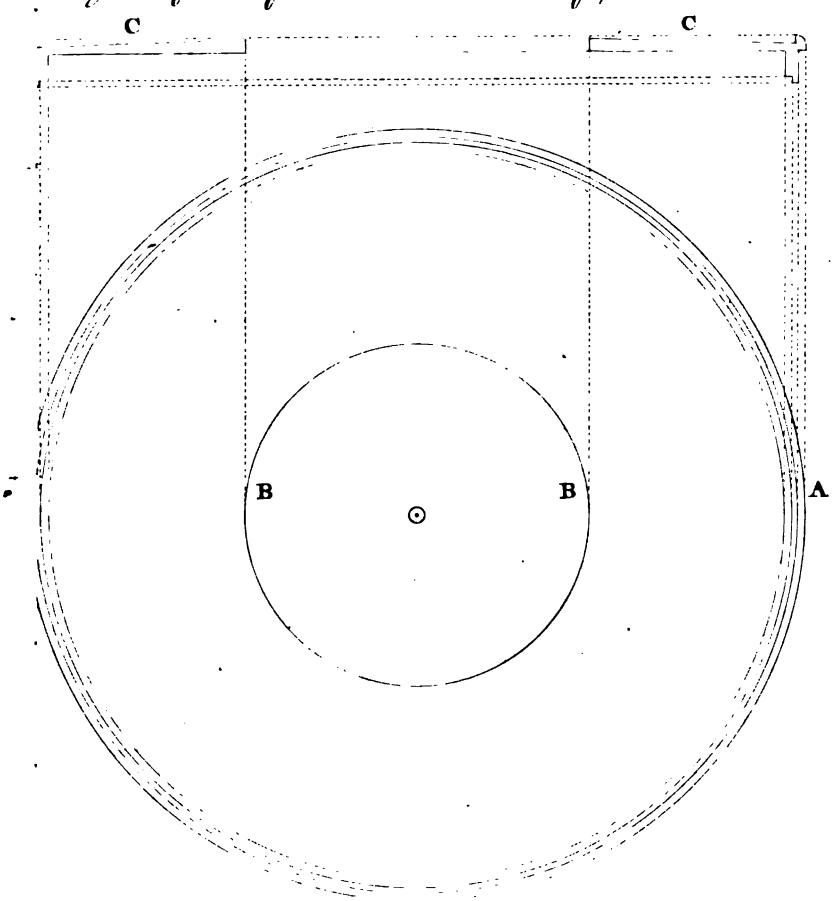

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Fig. 3.

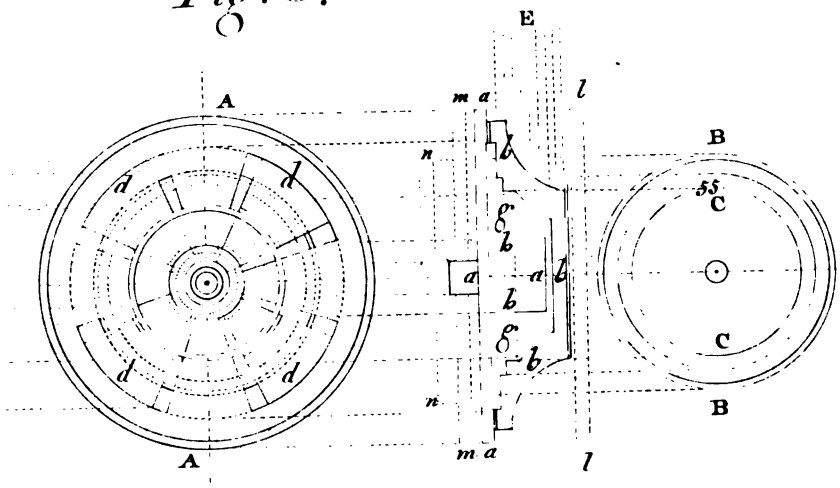
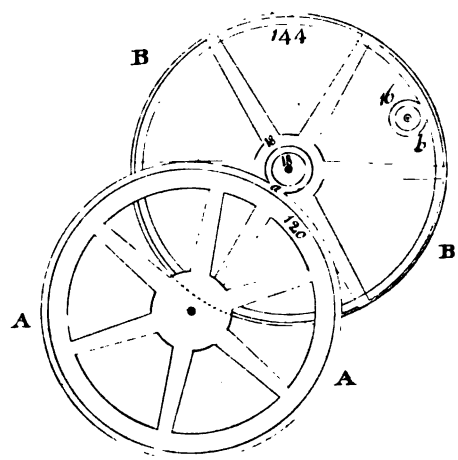


Fig. 4.



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The Discharger
Dial Plate than according to
may be even with the Plain of
are also drawn too broad at the
Hole in the Centre of the Wheel
that part of the Spindle which
0,108 of 1/4 Inch
th of the Spring 10 Inches.

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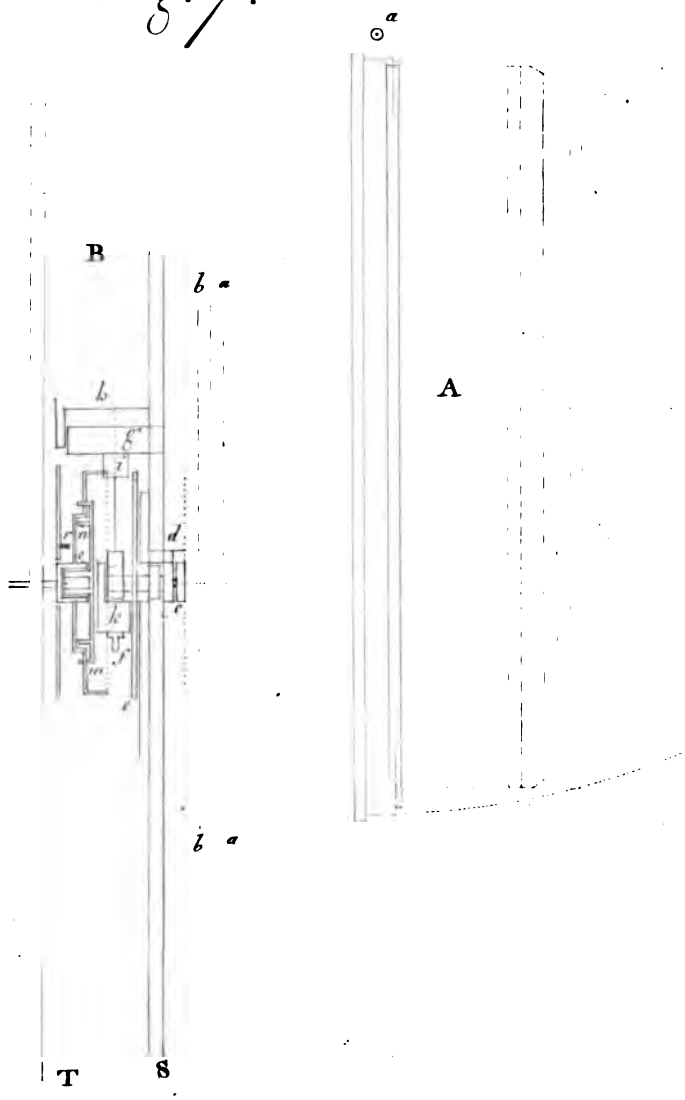
Fig. 7.



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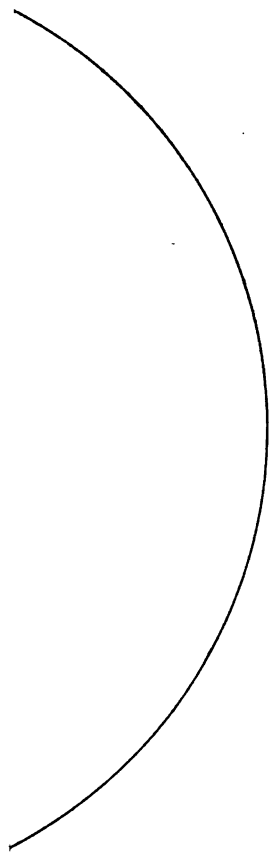

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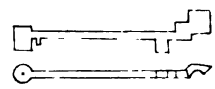
Fig. 11.



Diameter of the Hole in the Socket,
(its wider End) about 0, 17 of 1/4 Inch
Diameter of the Upper pivot 0, 22.
Diameter of the Lower pivot 0, 09.

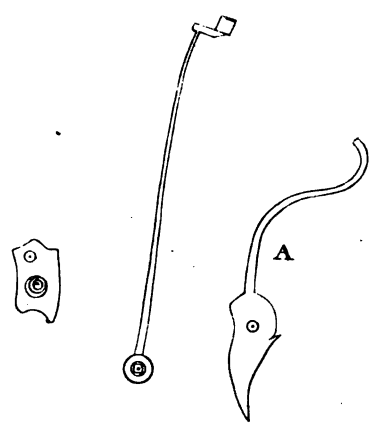


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Fig. 13.

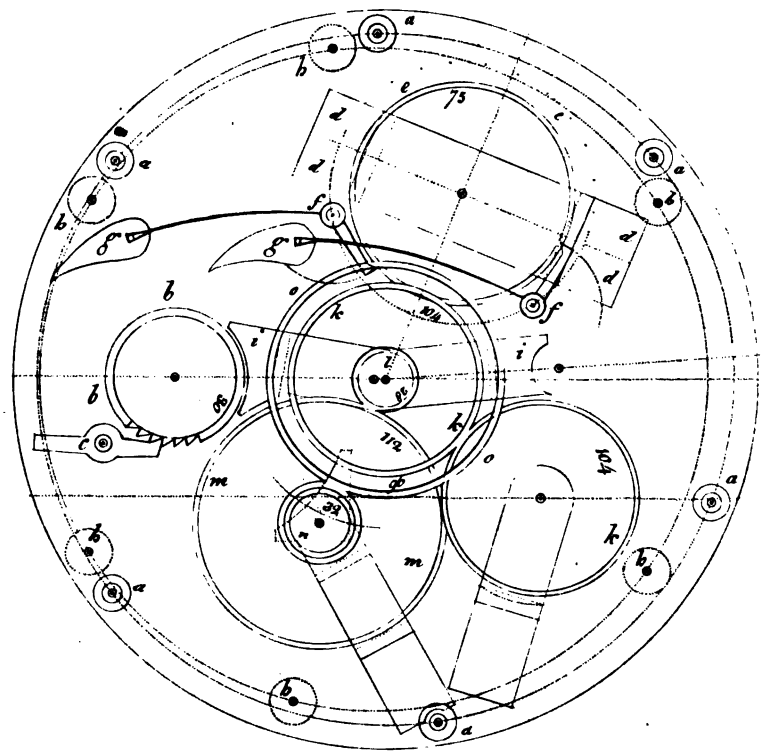

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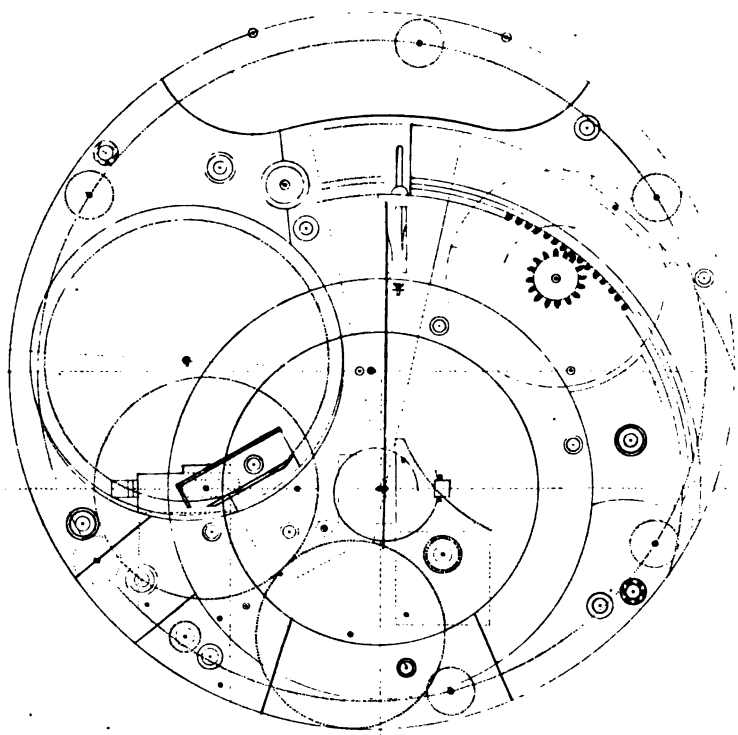
Fig. 15.

ver plate be 1/16 o Inch more?



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